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Specification

Optical sheet

Field of the invention

The present invention relates to an optical sheet having very fine surface irregularities such as a Fresnel lens sheet or a lenticular lens sheet to be used for a screen of a projection TV or a projector, or a condensing Fresnel lens sheet or an emboss sheet.

Background art

When a large size lens sheet such as Fresnel lens sheet, lenticular lens sheet, etc. is produced, it has been generally practiced to use a press method. According to this method, a planar lenticular mold having irregular surface pattern to match the irregular surface pattern of the desired lens surface is heated, and by pressing this lenticular mold onto a resin plate, irregular surface pattern on the surface of the lenticular mold is transferred to the resin plate. However, this press method has such problems that molding cycle is long and productivity is not very high. In this respect, a photo-polymer method (2P method) has been recently developed. According to this method, UV-setting resin is coated on a lenticular mold, and a resin plate is placed on it. Then, ultraviolet ray is irradiated to harden the UV-setting resin, and a large size lens sheet is formed. However, the productivity is

not sufficiently improved by the use of this 2P method.

On the other hand, another method is introduced, in which a metal mold having irregular surface pattern to match the irregular surface pattern of the desired lens is used, and a relatively small size optical sheet is molded by an injection molding method. In the injection molding method, molten resin is injected and filled in a cavity of the metal mold, and pressure is applied in the cavity via the molten resin in spool or runner until gate is cooled down and solidified (dwell pressure application process), and the pattern of the metal mold is transferred to the resin. After the gate is solidified, the resin in the metal mold is cooled down and solidified, and a molded product (optical sheet) is obtained.

The molten resin injected and filled in the cavity by the injection molding method is quickly cooled down when it is brought into contact with the surface of the cavity. A cooled and solidified layer is formed, and the molten resin is filled in the cavity. When the cooled and solidified layer is formed, pressure distribution occurs in the cavity as the molten resin is filled. This exerts action as residual stress of the molded product and causes warping, deformation, etc. after molding. Dwell pressure is applied to compensate shrinkage of the molded product after injection molding, and this also causes residual stress in the molded product.

If there is residual stress remaining in the molded product, warping, waviness, etc. are very likely to occur on the molded product when it is left under environmental condition of high

temperature and high humidity for long time. The larger and the thinner the molded product is, the higher the extent of warping and waviness is in the molded product.

To suppress the formation of the cooled and solidified layer, which causes the development of residual stress, attempts are made to increase temperature of the molten resin, to raise temperature of the metal mold, or to increase filling rate. In the past, however, there has been no attempt to study the standard value of residual stress remaining in the optical sheet after molding. Thus, each time the optical sheet is formed by changing the molding condition, it is necessary to determine whether the molding condition is adequate or not by performing long-term reliability test.

To solve the above problems, it is an object of the present invention to provide an optical sheet, which has lower residual stress and is free from warping, deformation, etc.

Disclosure of the invention

To attain the above object, the optical sheet according to the present invention is an optical sheet produced by injection molding method and having stress of up to 200 kg/cm^2 on surfaces of two opposing main planes. In this optical sheet, each of stresses on the surfaces of the two opposing main planes is preferably up to 200 kg/cm^2, and difference of stress on the two main planes is preferably within 20%. Here, "main planes" means two opposing

planes having large area and corresponding to exit surface of the light and to rear surface of the optical sheet. For instance, this optical sheet has an area or 4000 cm^2 or more and thickness of 4 mm or less.

The stress as described above is calculated as follows: A test piece of about 0.6 mm in width and having a mirror surface is prepared from the optical sheet. On the test piece thus obtained, retardation R of strain is determined under multiplication factor of x 5 using a Babinet compensator type precision strain gauge with Na light source. The stress is calculated by the following equation:

Strain (stress) = $R/(E \times T)$

where R is retardation, and T represents thickness (cm) of the test piece where retardation is measured, and E is a photoelastic constant [(nm/cm) $\times$ /(kg/cm^2)] of the material of the optical sheet.

Brief description of the drawings

Fig. 1 is a drawing to show a shape of a molded product produced using a metal mold No. 1 in an embodiment of the present invention;

Fig. 2 is a drawing to show a shape of a molded product produced using a metal mold No. 2 in an embodiment of the present invention;

Fig. 3 is a drawing to show a shape of a molded product produced using a metal mold No. 3 in an embodiment of the present invention;

Fig. 4 is a drawing to show a shape of a molded product produced using a metal mold No. 4 in an embodiment of the present invention;

Fig. 5 is a drawing to show a shape of a molded product produced using a metal mold No. 5 in an embodiment of the present invention;

Fig. 6 is a drawing to explain a measuring position and a measuring method of a deformation amount of an optical sheet. Fig. 6 (a) represents a measuring position, and Fig. 6 (b) shows a measuring method; and

Fig. 7 shows specification of each of the metal molds used in the Examples and the Comparative examples.

Best mode for carrying out the invention

When an optical sheet is produced by an injection molding method, one of the following methods is used to limit stress on the surface of the optical sheet up to 200 kg/cm^2: An ordinary injection method, an injection molding method under low pressure molding by reducing filling pressure, or an injection compression molding method. After the optical sheet is prepared by one of these methods, annealing (post-processing) should be performed so that the stress on the surface will be up to 200 kg/cm^2. Specifically, the optical sheet prepared by the injection compression molding method is sandwiched between glass plates. Then, annealing is performed for 2 - 4 hours at an environmental temperature, which is by 10 ℃ to 20 ℃ lower than deflection temperature under load (to be determined by the method such as ASTM D648) of a molding material, which constitutes the optical sheet.

Also, when the injection molding method (proposed in JP-

A-11-129305) is used, it is possible to limit the stress on the surface of the optical sheet to 200 kg/cm^2 or less without performing annealing procedure, depending on the preset molding condition. According to this injection molding method, a thin plate member such as nickel plate having a low thermal conductivity member (such as polyimide film) attached on its rear surface is placed in a cavity of a metal mold, and a molding material is filled in the metal mold. Near the surface of the metal mold where temperature is decreased from a level of transfer initiation temperature or higher to a level lower than the transfer initiation temperature, the molding material is cooled down through the contact with the metal mold. The low thermal conductivity member is designed to have such thickness that temperature of the molding material is again increased to the level higher than the transfer initiation temperature. According to this method, in the injection molding process, cavity volume of the metal mold is changed during injection and filling or after the completion of the filling of the synthetic resin. (Cavity volume is increased and then decreased, or it is decreased after increased.) By the use of the injection molding method (proposed in the specifications of JP-A-11-23863, and JP-A-11-36924), it is possible to limit the stress on the surface of the optical sheet to 200 kg/cm^2 or less without performing annealing procedure, depending on the preset molding condition.

There is no special restriction on the synthetic resin used in the injection molding so far as it is a transparent thermoplastic

resin. For instance, polymethyl methacrylate, polycarbonate, polystyrene, thermoplastic elastomer, non-crystalline polyolefin, polyamide, or copolymer of these substances may be used.

Detailed description will be given below on the present invention referring to the examples. The equipment and the devices used for the manufacture of the optical sheet in the examples are as follows:

(a) Injection molding machine

An injection molding machine "SG-150SYCAP M III" (trade name; product by Sumitomo Heavy Industries, Ltd.), or "MDIP-1400" (trade name; product by Meiki Co., Ltd.) was used.

(b) Metal mold

Five types of metal molds were used. The size of each of the metal molds was as follows:

(Metal mold No. 1)

This has a cavity of planar shape in size of 200 × 220 × 4.0 mm (length × width × thickness). On one of the main planes, a Fresnel lens pattern of 10 to 80 μm in height is formed. As shown in Fig. 1, a gate of 25 mm in width and 3.5 mm in thickness is provided at the center of lateral side of the metal mold. Gate of the lens sheet (optical sheet) is cut using heat nipper or saw blade. The configuration of the metal mold No. 1 is as shown in Fig. 7 (a). Thin plate members 5 are mounted on a movable side 3 and a fixed side 4, and the Fresnel lens pattern is formed on one of the thin plate members 5. When necessary, the member with low thermal

conductivity is attached on rear surface of the thin plate member.

(Metal mold No. 2)

This has a cavity of planar shape in size of 400 × 800 × 4.0 mm (length × width × thickness). On one of the main planes, a Fresnel lens pattern of 10 to 80 μm in height is formed. As shown in Fig. 2, a gate in size of 25 mm in width and 3.5 mm in thickness is provided at the center of lateral side of the metal mold. The configuration of the metal mold No. 2 is as shown in Fig. 7 (b). Thin plate members 5 are mounted on a moving side 3 and a fixed side 4 respectively, and the Fresnel lens pattern is formed on one of the thin plate members 5. When necessary, the member with low thermal conductivity is attached on rear surface of the thin plate member. The metal molds No. 3 to No. 5 have the same arrangement as the metal mold No. 2.

(Metal mold No. 3)

This has a cavity of planar shape in size of 500 × 900 × 2.0 mm (length × width × thickness). On one of the main planes, a Fresnel lens pattern of 10 to 80 μm in height is formed. As shown in Fig. 3, a gate of 25 mm in width and 1.5 mm in thickness is provided at the center of lateral side of the metal mold.

(Metal mold No. 4)

This has a cavity of planar shape in size of 700 × 900 × 2.0 mm (length × width × thickness). On one of the main planes, a Fresnel lens pattern of 10 to 80 μm in height is formed. On the

other surface, a prism pattern of 10 μm in height is formed. As shown in Fig. 4, a gate of 500 mm in width and 1.5 mm in thickness is provided at the center of lateral side of this metal mold.

(Metal mold No. 5)

This has a cavity of planar shape in size of 800 $\times$ 1000 $\times$ 2.0 mm (length $\times$ width $\times$ thickness). On one of main planes, a Fresnel lens pattern of 10 to 80 μm in height is formed. On the other surface, a prism pattern of 10 μm in height is formed. As shown in Fig. 5, a gate of 500 mm in width and 1.5 mm in thickness is provided at the center of lateral side of this metal mold.

(c) Molding material

A methacrylic resin molding material "Parapet GH-1000S" (trade name; product by Kuraray Co., Ltd.) was used.

(d) Method to measure stress on the surface of the molded product

Using a low speed saw "ISOMET" (trade name; product by Buehler), a piece in form of a tablet of about 0.6 mm in width was cut off from the molded product. By polishing both cutting surfaces using No. 2000 sandpaper and metal polishing agent, a test piece having mirror surface was prepared. On each of the test pieces thus obtained, distortion retardation R was determined under the magnification factor of $\times$ 5 using Na light source and a Babinet compensator type precision strain gauge "SVP-30 II" (trade name; product by Toshiba Glass Co., Ltd.). The stress was calculated by the following equation:

$$\text{Strain (stress)} = R/(3.8 \times T)$$

where R is retardation, and T represents thickness (cm) of the test piece at retardation measuring portion. The value 3.8 is a photoelastic constant [(nm/cm) / (kg/cm^2)] of polymethyl methacrylate.

(e) Method to measure transfer rate

Using a surface roughness measuring instrument Surfcorder "SE-30D" (trade name; product by Kosaka Laboratory Ltd.), the height of the pattern on the molded product was measured, and a ratio of pattern dimension of the molded product to pattern dimension of the metal mold used for the molding (dimension of molded product/dimension of metal mold) was calculated.

(f) Method to measure deformation amount

As shown in Fig. 6 (a) and Fig. 6 (b), the deformation amount of the optical sheet 1 was measured at each of the corners of the molded product. Specifically, the optical sheet 1 was placed on a platen 2, and a gap L between the platen 2 and the optical sheet 1 was measured using a thickness gauge, and a error between the form of the metal mold and the form of the optical sheet was determined.

(g) Constant temperature and humidity test

Reliability test of the optical sheet was performed using a constant temperature and humidity chamber (manufactured by Tabai Co., Ltd.). Testing condition was 50 ℃ at 80% relative humidity for 300 hours.

<u>Examples 1 to 5 and Comparative examples 1 to 5</u>

Using the injection molding machine described in (a) and the metal molds of (b) above, optical sheets were prepared under the molding condition and the annealing condition shown in Table 1. In each of the Examples and Comparative examples, injecting condition and cooling time were the same. The injecting condition was 100 cc/sec., and the cooling time was 60 sec. On the optical sheets thus obtained, stress on the surface layer where the Fresnel lens pattern was formed was measured by the measuring method of (d) above. Then, each optical sheet was left to stand under environmental condition of 50 ℃ and 80% relative humidity in the constant temperature and humidity chamber as given in (g) above. The amount of deformation after 300 hours was determined by the measuring method given in (f) above. The results are summarized in Table 2 and Table 3. As shown in Fig. 6, measuring position of the stress and the deformation shown in Tables 2 and 3 were as follows: Measuring positions A - D were at four corners of the lens sheet, and the measuring position E is at the center. (The same applies to Table 5 as given later.)

Table 1

	Molding machine	Resin temperature (℃) and metal mold temperature (℃)	Metal mold (Thin plate member (thickness in mm) /low thermal conductivity member (thickness in mm)	Annealing
Example 1	SG-150	270 80	Nickel (0.5)/None	80 ℃ for 3 hours. Then, gradually cooled down
Example 2	MDIP-1400	270 80	Nickel (0.5)/polyimide (0.1)	None
Example 3	MDIP-1400	270 80	Nickel (0.5)/polyimide (0.2)	None
Example 4	MDIP-1400	270 80	Nickel (0.5)/polyimide (0.3)	None
Example 5	MDIP-1400	270 80	Nickel (0.5)/polyimide (0.3)	None
Comparative example 1	SG-150	270 80	Nickel (0.5)/None	None
Comparative example 2	MDIP-1400	270 80	Nickel (0.5)/None	None
Comparative example 3	MDIP-1400	270 80	Nickel (0.5)/None	None
Comparative example 4	MDIP-1400	270 80	Nickel (0.5)/None	None
Comparative example 5	MDIP-1400	270 80	Nickel (0.5)/None	None

Table 2

	Metal mold No.	Stress on surface layer (kg/cm^2)		Pattern transfer rate	Deformation before test (mm)	Deformation after test (mm)
		Measuring position	Stress			
Example 1	1	A	117	0.90	0.02	0.21
		B	104	0.92	0.03	0.17
		C	96	0.91	0.03	0.14
		D	90	0.92	0.02	0.03
		E	100	0.95		
Example 2	2	A	155	0.94	0.02	0.30
		B	150	0.94	0.03	0.32
		C	122	0.93	0.02	0.20
		D	133	0.93	0.03	0.03
		E	145	0.95		
Example 3	3	A	175	0.96	0.04	0.23
		B	160	0.93	0.03	0.15
		C	132	0.97	0.02	0.20
		D	133	0.98	0.03	0.13
		E	145	0.95		
Example 4	4	A	170	0.90	0.05	0.35
		B	165	0.91	0.06	0.28
		C	142	0.95	0.05	0.25
		D	123	0.91	0.03	0.33
		E	145	0.90		
Example 5	5	A	170	0.96	0.07	0.20
		B	166	0.93	0.06	0.25
		C	143	0.92	0.03	0.28
		D	140	0.91	0.05	0.24
		E	155	0.95		

Table 3

	Metal mold No.	Stress on surface layer (kg/cm^2)		Pattern transfer rate	Deformation before test (mm)	Deformation after test (mm)
		Measuring position	Stress			
Example 1	1	A	225	0.95	0.04	2.54
		B	236	0.93	0.03	3.11
		C	223	0.94	0.04	2.20
		D	246	0.94	0.05	2.50
		E	235	0.93		
Example 2	2	A	255	0.93	0.13	5.35
		B	253	0.93	0.08	4.17
		C	230	0.94	0.10	3.83
		D	216	0.95	0.09	3.44
		E	215	0.92		
Example 3	3	A	265	0.91	0.23	5.30
		B	273	0.91	0.18	6.21
		C	251	0.92	0.13	4.30
		D	239	0.95	0.22	3.20
		E	241	0.97		
Example 4	4	A	325	0.90	0.43	3.35
		B	293	0.93	0.31	4.43
		C	260	0.95	0.21	3.22
		D	251	0.94	0.37	3.21
		E	315	0.90		
Example 5	5	A	288	0.90	0.32	4.23
		B	296	0.93	0.17	5.13
		C	275	0.95	0.19	4.83
		D	287	0.98	0.25	4.20
		E	264	0.97		

As shown in Tables 2 and 3, in the optical sheets of Examples 1 to 5 where stress on the surface layer was 200 kg/cm^2 or less, the deformation amount was low after the constant temperature and humidity test. On the other hand, in the optical sheets of Comparative examples 1 to 5 where stress on the surface layer was more than 200 kg/cm^2, the deformation amount after the constant temperature and humidity test was higher. On the lens sheets of

Examples 1 to 5, deformation amount was lower in each of the following tests: (1) a test to dry up at 70 ℃ for 300 hours; (2) a test to leave the sheet at -20 ℃ for 300 hours; and (3) a test to leave the sheet alternately at low temperature of -20 ℃ and at high temperature of +70 ℃ and to repeat this for 100 cycles.

<u>Examples 6 to 13</u>

Using the injection molding machine of (a) and the metal molds given in (b) above, optical sheets were prepared under the molding condition and the annealing condition shown in Table 4. In each of these Examples, the injecting condition and the cooling time were the same. The injecting condition was 100 cc/sec., and the cooling time was 60 sec. On the lens sheets thus obtained, stress was determined by the measuring method given in (d) above on the surface layer where the Fresnel lens pattern was formed and the surface where the Fresnel lens pattern was not formed (mirror surface). Then, the deformation amount was measured by the same procedure as in Examples 1 to 5. The results are summarized in Table 5.

Table 4

	Molding machine	Metal mold temperature (℃)		Metal mold (Thin plate member (thickness in mm) /low thermal conductivity member (thickness in mm)	Annealing
		Prism surface side	Fresnel lens side		
Example 6	SG-150	80	80	Nickel (0.5)/None	80 ℃ for 3 hours
Example 7	MDIP-1400	80	80	Nickel (0.5)/polyimide (0.1)	None
Example 8	MDIP-1400	80	80	Nickel (0.5)/polyimide (0.2)	None
Example 9	MDIP-1400	80	80	Nickel (0.5)/polyimide (0.3)	None
Example 10	MDIP-1400	80	80	Nickel (0.5)/polyimide (0.3)	None
Example 11	SG-150	80	70	Nickel (0.5)/None	80 ℃ for 2 hours
Example 12	MDIP-1400	60	80	Nickel (0.5)/polyimide (0.1)	None
Example 13	MDIP-1400	60	80	Nickel (0.5)/polyimide (0.2)	None

Table 5

	Metal mold No.	Stress on surface layer (kg/cm^2)			Pattern transfer rate	Deformation before test (mm)	Deformation after test (mm)
		Measuring position	Stress (prism surface side)	Stress (Fresnel lens side)			
Example 6	1	A	127	138	0.93	0.02	0.25
		B	136	125	0.99	0.03	0.27
		C	108	98	0.93	0.01	0.13
		D	102	105	0.92	0.03	0.15
		E	123	118	0.93		
Example 7	2	A	175	180	0.92	0.03	0.34
		B	150	145	0.90	0.03	0.32
		C	122	113	0.92	0.04	0.27
		D	133	124	0.93	0.06	0.15
		E	127	120	0.96		
Example 8	3	A	185	160	0.93	0.04	0.36
		B	170	155	0.94	0.03	0.25
		C	152	134	0.98	0.03	0.20
		D	140	137	0.95	0.02	0.23
		E	185	163	0.95		
Example 9	4	A	163	180	0.90	0.04	0.41
		B	176	155	0.92	0.05	0.23
		C	142	126	0.94	0.07	0.45
		D	153	175	0.93	0.07	0.25
		E	132	138	0.92		
Example 10	5	A	145	166	0.91	0.04	0.16
		B	175	155	0.92	0.07	0.35
		C	148	133	0.95	0.05	0.37
		D	132	143	0.95	0.08	0.51
		E	180	165	0.94		
Example 11	1	A	120	162	0.93	0.01	2.21
		B	125	163	0.93	0.03	2.12
		C	110	146	0.94	0.03	1.87
		D	100	146	0.95	0.04	2.60
		E	124	138	0.90		
Example 12	2	A	185	145	0.92	0.33	3.45
		B	170	133	0.92	0.25	3.23
		C	150	111	0.94	0.28	2.48
		D	147	100	0.95	0.23	2.51
		E	146	110	0.96		
Example 13	3	A	195	152	0.94	0.35	3.75
		B	174	133	0.95	0.33	4.16
		C	140	105	0.96	0.41	3.48
		D	155	110	0.96	0.32	3.51
		E	148	113	0.90		

As shown in Table 5, in the optical sheets of Examples 6 to 10 where stress on the surface layer was 200 kg/cm^2 or less and difference of stress between front surface and rear surface was within 20%, deformation amount after test was very low. On the other hand, in the optical sheets of Examples 11 to 13 where difference of stress between front surface and rear surface was more than 20% although the stress on the surface layer was 200 kg/cm^2 or less, deformation amount after test was somewhat higher.

Industrial applicability

As described above, in the optical sheet complying with the standard value of the residual stress of the surface according to the present invention, neither warping nor deformation occurs after molding. This optical sheet can be used in the applications such as Fresnel lens sheet or lenticular lens sheet to be used for a screen of a projection TV, a projector, etc., and as a condensing Fresnel lens sheet, an emboss sheet, etc.